Reverse total shoulder arthroplasty for massive, irreparable rotator cuff tears before the age of 60 years: long-term results

Ernstbrunner, Lukas ; Suter, Aline ; Catanzaro, Sabrina ; Rahm, Stefan ; Gerber, Christian

Abstract: BACKGROUND: There has been serious concern regarding the longevity and durability of outcomes of reverse total shoulder arthroplasty (RTSA) in younger patients. It was the purpose of this study to analyze long-term outcomes and complications of RTSA for irreparable rotator cuff tears in patients younger than 60 years. METHODS: Twenty patients (23 shoulders) with a mean age of 57 years (range, 47 to 59 years) were evaluated at a mean of 11.7 years (range, 8 to 19 years) after RTSA. Fifteen shoulders (65%) had undergone previous non-arthroplasty surgery. Longitudinal clinical and radiographic outcomes were assessed. RESULTS: At the time of final follow-up, the mean absolute and relative preoperative Constant score (CS) (and standard deviation) had improved from 24 ± 9 to 59 ± 19 points ($p < 0.001$) and from 29% ± 11% to 69% ± 21% ($p < 0.001$), respectively. The mean Subjective Shoulder Value (SSV) had increased from 20% ± 13% to 71% ± 27% ($p < 0.001$). There were also significant improvements in the mean active anterior elevation (from 64° to 117°), active abduction (from 58° to 111°), pain scores, and strength (all p 0.001). Clinical outcomes did not significantly deteriorate beyond 10 years and the functional results of patients with previous surgical procedures were not significantly inferior to the results of those with primary RTSA. The grade of, and number of patients with, radiographically apparent notching increased over time; the mean relative CS was lower in patients in whom the notching was grade 2 or higher (57%) than it was in those with no or grade-1 notching (81%; $p = 0.006$). Nine (39%) had 1 complication, with 2 failed RTSAs (9%). CONCLUSIONS: RTSA in patients younger than 60 years leads to substantial subjective and functional improvement without clinical deterioration beyond 10 years. It is associated with a substantial complication rate, and complications compromise ultimate subjective and objective outcomes. LEVEL OF EVIDENCE: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

DOI: https://doi.org/10.2106/JBJS.17.00095

Reverse Total Shoulder Arthroplasty for Massive, Irreparable Rotator Cuff Tears Before the Age of 60 Years

Long-Term Results

Lukas Ernstbrunner, MD, Aline Suter, MD, Sabrina Catanzaro, RN, Stefan Rahm, MD, and Christian Gerber, MD

Investigation performed at the Balgrist University Hospital, Zurich, Switzerland

Background: There has been serious concern regarding the longevity and durability of outcomes of reverse total shoulder arthroplasty (RTSA) in younger patients. It was the purpose of this study to analyze long-term outcomes and complications of RTSA for irreparable rotator cuff tears in patients younger than 60 years.

Methods: Twenty patients (23 shoulders) with a mean age of 57 years (range, 47 to 59 years) were evaluated at a mean of 11.7 years (range, 8 to 19 years) after RTSA. Fifteen shoulders (65%) had undergone previous non-arthroplasty surgery. Longitudinal clinical and radiographic outcomes were assessed.

Results: At the time of final follow-up, the mean absolute and relative preoperative Constant score (CS) (and standard deviation) had improved from 24 ± 9 to 59 ± 19 points ($p < 0.001$) and from 29% ± 11% to 69% ± 21% ($p < 0.001$), respectively. The mean Subjective Shoulder Value (SSV) had increased from 20% ± 13% to 71% ± 27% ($p < 0.001$). There were also significant improvements in the mean active anterior elevation (from 64° to 117°), active abduction (from 58° to 111°), pain scores, and strength (all $p \leq 0.001$). Clinical outcomes did not significantly deteriorate beyond 10 years and the functional results of patients with previous surgical procedures were not significantly inferior to the results of those with primary RTSA. The grade of, and number of patients with, radiographically apparent notching increased over time; the mean relative CS was lower in patients in whom the notching was grade 2 or higher (57%) than it was in those with no or grade-1 notching (81%; $p = 0.006$). Nine (39%) had ≥1 complication, with 2 failed RTSAs (9%).

Conclusions: RTSA in patients younger than 60 years leads to substantial subjective and functional improvement without clinical deterioration beyond 10 years. It is associated with a substantial complication rate, and complications compromise ultimate subjective and objective outcomes.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

After catastrophic results with early designs[1], reverse total shoulder arthroplasty (RTSA) experienced a renaissance upon the introduction of new biomechanical concepts in the late 1980s[2]. Initially, this new RTSA was performed in elderly, low-demand patients with an insufficient rotator cuff and an intact deltoid muscle[3-11]. With increasing clinical knowledge and biomechanical understanding, indications for RTSA were expanded[5,8,9,11-20].

Although RTSA had good functional short-term and mid-term results[6,7,11,16], functional deterioration was observed after 6 to 8 years and substantial changes were seen on radiographs after 10 years; this raised serious concern, especially regarding younger, more active patients[7,12,21]. Short-term and mid-term results of RTSA for irreparable rotator cuff tears in patients 65 years old or younger showed sustained, substantial improvement in pain levels and function compared with the preoperative status[22-25]. Whether longer-term functional improvement in young and active individuals persists, however, remains a major concern.

It was the purpose of this study to analyze whether improvement in long-term clinical and radiographic outcomes outweighs the potential complications of RTSA for massive, irreparable rotator cuff tears with pseudoparalysis in patients

Disclosure: There was no external source of funding for this study. On the **Disclosure of Potential Conflicts of Interest** forms, *which are provided with the online version of the article,* one or more of the authors checked "yes" to indicate that the author had a relevant financial relationship in the biomedical arena outside the submitted work (http://links.lww.com/JBJS/E357).

TABLE I Types of Previous Failed Operations in 15 Shoulders

	No. of Shoulders
1 previous operation	10
Rotator cuff repair	8
Rotator cuff debridement	2
2 previous operations	3
Rotator cuff repairs (2)	2
Rotator cuff repair (1) and cuff debridement (1)	1
4 previous operations	1
Rotator cuff repair (1) and cuff debridement (3)	1
5 previous operations	1
Rotator cuff repair (1), deltoid flap (1), revision of deltoid flap (1), osteotomy of acromion (1), and removal of implants (1)	1

younger than 60 years of age. It was hypothesized that the functional outcomes in this young patient group would remain significantly improved beyond 10 years and that management of complications is possible.

Materials and Methods

Patients

From May 1997 to May 2008, 29 shoulders in 26 consecutive patients (15 men and 11 women; mean age, 57 years [range, 47 to 59 years]) with a massive, irreparable rotator cuff tear and secondary pseudoparalysis of active anterior elevation were treated with RTSA. All patients gave written consent to participate in the study, and the responsible review board approved the study.

Patients with active anterior elevation of <90° and preserved free passive anterior elevation were considered to have pseudoparalysis. The rotator cuff was considered to be irreparable if pseudoparalysis was chronic, if the acromiohumeral distance was <7 mm on an anteroposterior radiograph, and/or if fatty infiltration of the supraspinatus and infraspinatus muscles was greater than stage 2 according to the Goutallier classification[26] or the modification of that classification for magnetic resonance imaging (MRI)[27]. Only patients with a minimum of 8 years of clinical and radiographic follow-up were included.

At the time of final follow-up, 3 patients (12%) had died and 3 (12%) had been lost to follow-up. None of these patients had any complications or revision surgery as confirmed by institutional records or telephone.

The study cohort consisted of 20 patients (11 men and 9 women) with a total of 23 affected shoulders. Their mean age was 57 years (range, 47 to 59 years) at the time of the index procedure. The dominant shoulder was involved in 17 cases (74%). Patients were examined in person at a mean of 11.7 years (range, 8 to 19 years). The RTSA was the primary procedure in 8 shoulders (35%) and was performed as revision surgery in

TABLE II Complications and Treatment in 9 (39%) of the 23 Shoulders

Complication	No. of Shoulders	Definitive Treatment
Persistent stiffness	1	Nonoperative
Persistent pain	1	Arthroscopic debridement
Mechanical block	1	Arthroscopic removal of avulsed greater tuberosity
Early dislocation (<6 wk)	1	Open reduction and change of liner
Late dislocation	3	Closed reduction (n = 2; 50 and 60 mo). Open reduction and change of liner (n = 1; 64 mo*)
Glenoid component dissociation	1	Conversion to hemiarthroplasty (76 mo)
Infection	2	Debridement, change of liner, and antibiotics (n = 1; 64 mo*). Debridement and change of liner (n = 1; 18 mo†). Removal of prosthesis and insertion of cement spacer (n = 1; 29 mo†)

*Same patient, who developed infection after liner exchange and was finally treated with debridement, another liner exchange, and intravenous antibiotics. †Same patient, who had persistent infection after debridement and liner exchange and was finally treated with component removal and insertion of a cement spacer.

Fig. 1-A

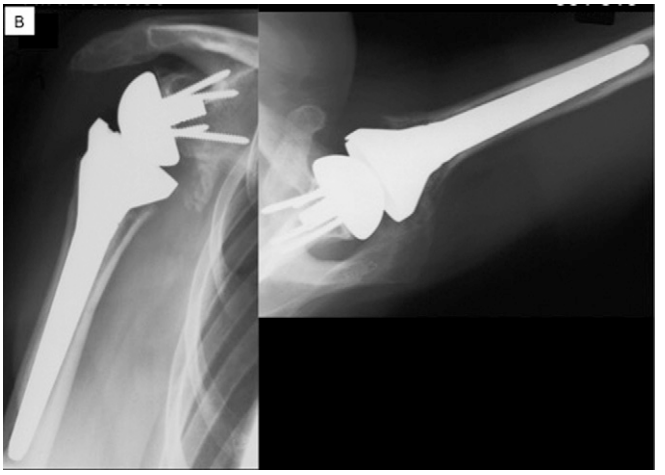

Fig. 1-B

Figs. 1-A through 1-D Functional results 15 years after failed RTSA. **Fig. 1-A** Preoperative radiographs demonstrating acetabularization of the acromion and glenohumeral arthritis consistent with a cuff tear arthropathy. **Fig. 1-B** At the age of 59 years, a RTSA was performed. The patient developed a deep infection 18 months postoperatively.

15 (65%), 5 of which underwent >1 previous shoulder surgical procedure other than RTSA (Table I). According to the classification of Hamada et al.[28], 14 shoulders (61%) demonstrated radiographic evidence of glenohumeral arthritis (stage 4 or 5), whereas 9 (39%) showed no signs of glenohumeral arthritis (stage 1, 2, or 3). The preoperative morphologic appearance of the teres minor muscle on computed tomography (CT) or MRI was classified in 22 shoulders according to the system of Walch et al.[29,30] and graded as normal in 11 shoulders (50%), as hypertrophic in 2 (9%), as atrophic in 5 (23%), and as absent in 4 (18%).

Clinical and Radiographic Assessment

Functional and radiographic results were included only if the RTSA implant was still in situ (n = 21) at the time of final follow-up. Clinical and radiographic examination was performed preoperatively and at 1, 2 to 5, 5 to 8, 8 to 10, and >10 years postoperatively.

Examiners who had not operated on the patients assessed the outcome in an institutionally standardized manner at each time point. Clinical examination included measurement of the active and passive ranges of motion using a handheld goniometer while the patient was seated and assessment of the absolute Constant score (aCS) and relative Constant score (rCS, which is a percentage of age and sex-matched normal scores)[31,32] as well as the Subjective Shoulder Value (SSV)[33]. Patients rated their overall postoperative results as "excellent," "good," "fair," or "unsatisfactory." Abduction strength was measured with a validated electronic dynamometer (Isobex; Cursor)[34].

Preoperatively and postoperatively, standardized true anteroposterior, axillary lateral, and scapular lateral radiographs were made for all patients. Outcome measures evaluated on the postoperative radiographs were inferior scapular notching, radiolucency, and glenoid or humeral loosening. Inferior scapular notching was graded as described by Sirveaux et al.[16]. Radiolucency around the components was defined as grade 0 (no radiolucent line), grade 1 (incomplete 1-mm line), grade 2 (complete 1-mm line), grade 3 (incomplete 1.5-mm line), grade 4 (complete 1.5-mm line), or grade 5 (complete 2-mm line)[35].

Two independent shoulder surgeons who were both blinded to the clinical results analyzed the radiographs.

Surgical Technique

The surgical technique for the RTSA was performed as described by Werner et al.[8]. The Delta III reverse shoulder prosthesis (DePuy) was implanted in 14 shoulders (61%) and the Anatomical Shoulder Reverse prosthesis (Zimmer), in 9 (39%). The humeral component was cemented in place with gentamicin-impregnated bone cement (Palacos; Heraeus Kulzer) in 12 shoulders (52%). The native glenoid was replaced with a glenosphere

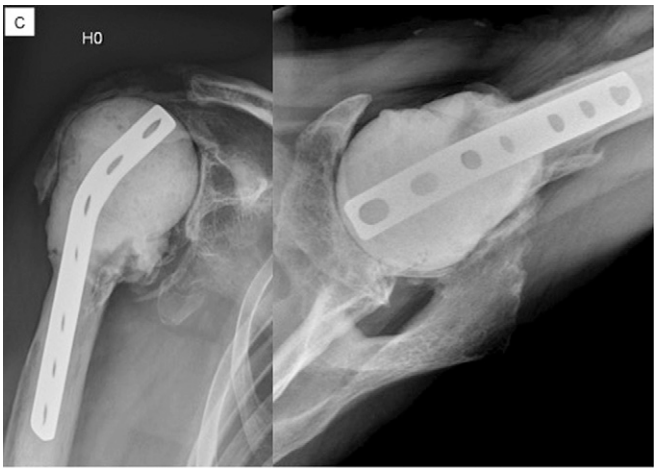

Fig. 1-C

The infection led to component removal and insertion of a cement spacer molded around a locking plate.

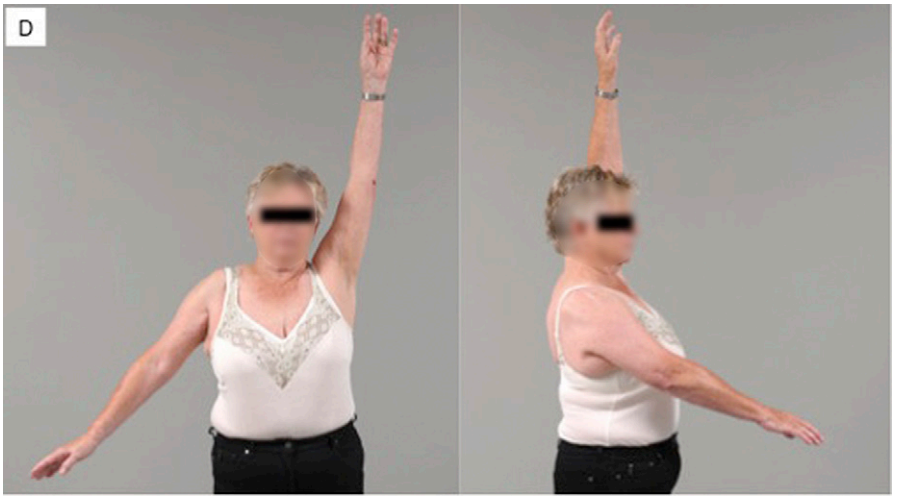

Fig. 1-D
At the clinical examination 15 years later, the patient was satisfied, reported mild pain, and had acceptable shoulder function.

with a diameter of 36 mm in 18 shoulders (78%), 40 mm in 4 shoulders (17%, all Anatomical), and 42 mm in 1 (4%, Delta III). All shoulders treated with a Delta III RTSA received a standard lateralized humeral polyethylene cup, whereas a +6-mm medializing offset humeral cup was implanted in the Anatomical replacements. At the preoperative examination, 3 patients showed combined loss of active anterior elevation and external rotation and underwent RTSA with concurrent latissimus dorsi transfer according to the recommendation of, and with the technique described by, Gerber et al.[36].

Statistical Analysis

The Shapiro-Wilk test was applied to test the data for normal distribution. Preoperative and postoperative functional scores were compared using the paired t test (normal data) and the Wilcoxon signed-ranks test (non-normal data). The Kruskal-Wallis test and the Mann-Whitney U test were applied for subgroup analysis. The Fisher exact test was used for categorical variables. The Pearson correlation coefficient was calculated to assess bivariate correlation between postoperative outcome measures and the number of previous operations, Hamada stage of the massive rotator cuff tear, and morphologic appearance of the teres minor muscle. Implant survivorship in the entire series (including the 6 patients who died or were lost to follow-up) was assessed using Kaplan-Meier curve analysis. The alpha level was set at 0.05, and all p values were 2-tailed.

The interobserver reliability of the assessments of the Hamada stage of the massive rotator cuff tear, morphologic

Fig. 2-A

Fig. 2-B

Figs. 2-A through 2-D Functional and radiographic outcomes 18 years after a right-sided RTSA performed at the age of 56 years. **Fig. 2-A** Preoperative radiographs demonstrating superior migration of the humeral head with mild degenerative changes of the glenohumeral joint due to a massive, irreparable rotator cuff tear. **Fig. 2-B** Anteroposterior and axillary lateral radiographs made 64 months after the RTSA show a reduced distance between the humeral component and the glenosphere with a dislocated polyethylene liner (asterisk). Two weeks after exchange of the polyethylene liner, the patient developed a deep infection necessitating another revision with liner exchange, aggressive debridement, and treatment with intravenous antibiotics.

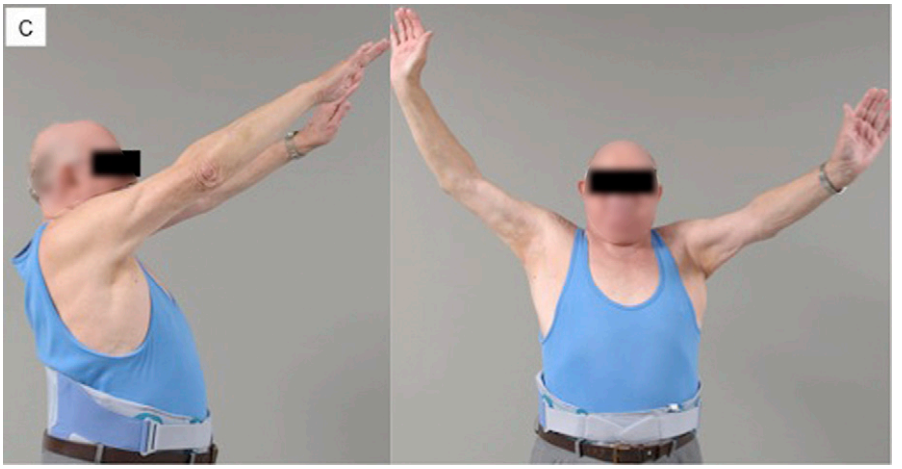

Fig. 2-C
Clinical photographs made 18 years after the original procedure demonstrate good active anterior elevation and abduction.

appearance of the teres minor muscle, and scapular notching was measured by calculating the intraclass correlation coefficient (ICC) for absolute agreement, with 1 indicating perfect reliability.

Results

Complications

Nine shoulders (39%) had ≥1 postoperative complication (Table II). With the available data, neither previous surgery nor the severity of preoperative glenohumeral arthritis was found to be significantly associated with postoperative complications ($p = 0.633$ and 0.383). The complication rate for the shoulders without prior surgery was 38% (3 of 8) compared with 40% (6 of 15) for those that had undergone surgery prior to RTSA. The complication rate for the shoulders without glenohumeral arthritis (Hamada stage 1, 2, or 3) was 56% (5 of 9) compared with 29% (4 of 14) for those with glenohumeral arthritis (Hamada stage 4 or 5).

Reoperations, Revisions, and Failures

Overall, ≥1 reoperation was performed in 6 shoulders (26%), 5 of which had undergone previous surgery. The average time from the RTSA to the reoperation was 28 months; 2 reoperations were due to early complications and 4, to late complications. Four open revisions (17%) were performed, including exchange of the polyethylene liner because of instability (n = 2), conversion to hemiarthroplasty (n = 1), and implant removal and insertion of a cement spacer (n = 1). The conversion to hemiarthroplasty was performed after dissociation of a glenoid component 76 months after the original procedure in a patient with severe ankylosing spondylitis and severe preoperative glenoid erosion. At the latest follow-up evaluation, the patient was satisfied, reported no pain, and had an SSV of 45%. The cement spacer was implanted in a patient who had undergone 5 surgical procedures prior to the index operation and who had developed a deep infection 18 months after the RTSA. She declined additional surgery after the spacer implantation (Figs. 1-A through 1-D). These 2 patients had the 2 failures (9%) in this series.

Dislocation occurred in 4 (17%) of the shoulders (Table II). One dislocation occurred within the first 6 weeks postoperatively and was treated with open reduction and insertion of a thicker polyethylene liner. The patient had a stable RTSA at the time of final follow-up. The other 3 dislocations were late complications, occurring after 50, 60, and 64 months. Two patients were treated with closed reduction and had a stable RTSA at the time of final follow-up. The dislocation that occurred after 64 months was treated with open reduction and insertion of a thicker polyethylene liner. This patient subsequently developed a deep infection, which was treated with aggressive debridement and postoperative intravenous antibiotics without any additional complications (Figs. 2-A through 2-D).

Clinical Outcomes

The 2 shoulders (9%) that had a failure were not included in the analysis of the clinical outcomes. The mean aCS and rCS, active anterior elevation, active abduction, and SSV of the remaining

Fig. 2-D
Radiographs demonstrate advanced inferior scapular notching without any signs of component loosening.

TABLE III Clinical Findings Preoperatively and at Final Follow-up

Variable	Preoperative	Postoperative	Change	P Value
Shoulders* *(no.)*	21	21		
CS†				
Absolute *(points)*	24 ± 9	59 ± 19	+35	<0.001
Relative *(%)*	29 ± 11	69 ± 21	+40	<0.001
Pain *(points)*	6 ± 4	13 ± 4	+7	<0.001
Strength *(points)*	0.7 ± 1.7	7.5 ± 7.9	+6.8	0.001
SSV† *(%)*	20 ± 13	71 ± 27	+51	<0.001
Range of motion† *(°)*				
Active anterior elevation	64 ± 32	117 ± 34	+53	<0.001
Abduction	58 ± 30	111 ± 47	+53	<0.001
External rotation	28 ± 26	26 ± 19	−2	0.749
Satisfaction *(no. [%])*				
Excellent		13 (62)		‡
Good		2 (10)		‡
Fair		5 (24)		‡
Unsatisfactory		1 (5)		‡

*The 2 shoulders that underwent removal of the RTSA were excluded from the analysis of postoperative clinical results. †The data are presented as the mean and standard deviation. ‡Descriptive analysis with absolute and relative values only.

21 shoulders significantly improved compared with the preoperative status (Table III). The mean active external rotation remained unchanged (28° compared with 26°; p = 0.749). Of the 3 patients who underwent a concurrent latissimus dorsi transfer, 2 had 20° of active external rotation and 1 had 40°, which corresponded to an improvement of 40° in 2 and 20° in 1. The functional outcomes and SSV showed no significant deterioration within the entire observation period (Table IV).

One patient, who had an SSV of 0% due to persistent pain and poor shoulder function, was dissatisfied with the outcome. This patient had had 4 previous surgical procedures and 1 arthroscopic reoperation and declined any more treatment.

Neither the mean rCS nor the mean SSV was significantly influenced by the severity of the preoperative cuff tear arthropathy, the morphologic appearance of the teres minor muscle, or previous surgery (p > 0.05). Also, the mean active external rotation was not affected by the state of the teres minor muscle in this small cohort (p = 0.942). The number of previous surgical procedures, however, correlated with the postoperative pain level (r = −0.59; p = 0.005) and SSV (r = −0.51; p = 0.019).

TABLE IV Postoperative Longitudinal Clinical Results

Variable	2-5 Years	5-8 Years	8-10 Years	10-18 Years	P Value
Shoulders *(no.)*	18	17	18	17	
CS*					
Absolute *(points)*	55 ± 18	61 ± 16	62 ± 18	57 ± 20	0.771
Relative *(%)*	63 ± 20	70 ± 17	72 ± 20	67 ± 23	0.482
Pain *(points)*	12 ± 3	13 ± 3	13 ± 3	12 ± 4	0.240
Strength *(points)*	4.4 ± 4.5	4.8 ± 4.4	7.4 ± 5.2	7.5 ± 8.5	0.364
SSV* *(%)*	65 ± 27	68 ± 23	73 ± 24	66 ± 28	0.802
Range of motion* *(°)*					
Active anterior elevation	122 ± 32	124 ± 34	119 ± 33	115 ± 37	0.858
Abduction	114 ± 37	114 ± 38	118 ± 46	111 ± 49	0.982
External rotation	26 ± 21	27 ± 25	26 ± 28	24 ± 22	0.960

*The data are presented as the mean and standard deviation.

TABLE V Evolution of Inferior Scapular Notching Over Time

	No. (%) of Shoulders					
Notch Grade	<1 Year	2-5 Years	5-8 Years	8-10 Years	10-18 Years	Latest Follow-up
No notching	13 (62)	1 (5)	1 (6)	1 (5)	1 (6)	1 (5)
Grade 1	6 (29)	14 (70)	11 (65)	12 (63)	7 (41)	10 (48)
Grade 2	2 (10)	4 (20)	2 (12)	3 (16)	4 (24)	4 (19)
Grade 3	0	0	2 (12)	2 (11)	3 (18)	4 (19)
Grade 4	0	1 (5)	1 (6)	1 (5)	2 (12)	2 (10)
Total	21	20	17	19	17	21

Patients with complications but retained implants (n = 7) had inferior results with regard to the mean rCS (60% versus 74%), active anterior elevation (108° versus 122°), and active abduction (99° versus 117°) ($p < 0.05$ for all) as well as with respect to the mean postoperative pain level (10 versus 14 points; $p = 0.025$) and SSV (51% versus 80%; $p = 0.047$) compared with patients without complications. The functional outcomes, postoperative pain levels, and SSVs did not deteriorate significantly over time in the group with complications ($p > 0.05$). The mean preoperative rCS for patients with complications that did not result in implant removal (23%) was significantly inferior to that of patients without any complications (33%; $p = 0.047$). Therefore, the mean improvement in rCS, pain level, and SSV did not differ significantly different between the shoulders with complications (37%, 5 points, and 35%, respectively) and those without any complications (43%, 8 points, and 58%; $p > 0.05$).

Radiographic Outcome

The 2 failures (9%) were not included in the analyses of the radiographic results.

There were no signs of loosening of the humeral stem or glenoid component at the latest follow-up evaluation.

Inferior scapular notching was found in 20 (95%) of the shoulders. The number with, and the degree of, notching increased over time (Table V). Patients with scapular notching of grade 2 or higher (n = 10) had a significantly lower mean rCS (57% versus 81%; $p = 0.006$) and SSV (54% versus 86%; $p = 0.003$) at the time of final follow-up compared with patients with no or grade-1 notching (n = 11). Patients with no

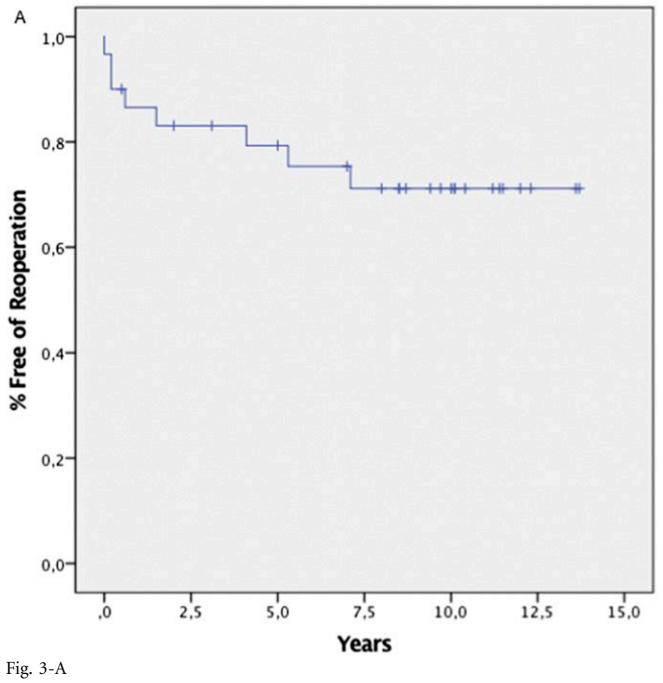

Fig. 3-A

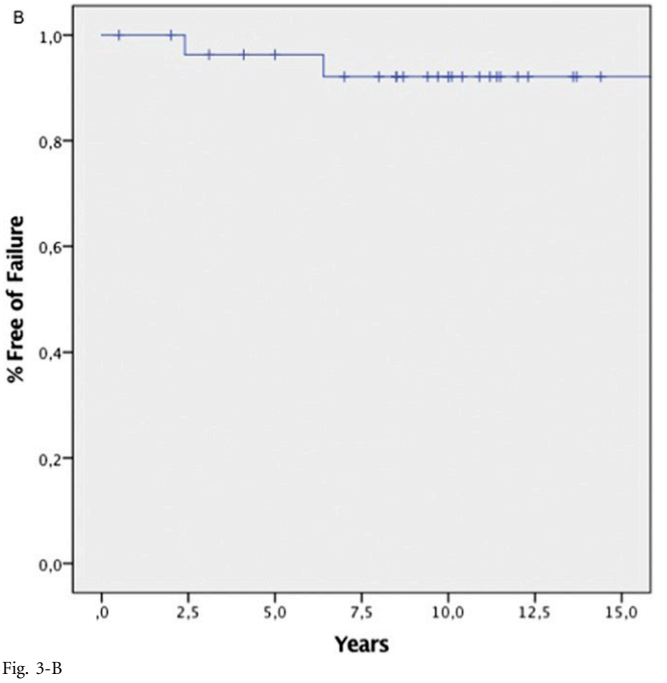

Fig. 3-B

Figs. 3-A and 3-B Kaplan-Meier survivorship analysis. **Fig. 3-A** The rate of survival free of any reoperation was 82% at 5 years and 74% at 10 years. **Fig. 3-B** The rate of survival with conversion to hemiarthroplasty or implant removal and cement spacer insertion as the end points was 96% at 5 years and 92% at 10 years.

or grade-1 notching had significantly better mean active anterior elevation (136° versus 97°; p = 0.006) and active abduction (137° versus 82°; p = 0.010) as well as significantly less pain (10 versus 15 points; p = 0.007). Preoperatively, patients who ultimately had no or minimal notching had a mean of 20° more active anterior elevation (73° versus 53°; p = 0.189) and 19° more active abduction (67° versus 48°; p = 0.251) than those who ultimately had advanced notching, although these preoperative differences did not reach significance in this small cohort.

The assessments of the preoperative stages of massive rotator cuff tear arthritis (r = 0.89; 95% confidence interval [CI] = 0.76 to 0.95), morphologic appearance of the teres minor muscle (r = 0.84; 95% CI = 0.66 to 0.93), and scapular notching (r = 0.87; 95% CI = 0.70 to 0.94) had very good interobserver reliability.

Survival Analysis

The overall rate of survival without a reoperation was 82% at 5 years and 74% at 10 years (Fig. 3-A). The survival rate with failure of the RTSA as the end point was 96% at 5 years and 92% at 10 years (Fig. 3-B).

Discussion

All patients included in the present series were younger than 60 years of age and had a painful, dysfunctional shoulder due to an irreparable rotator cuff tear, which was associated with glenohumeral osteoarthritis in 14 (61%) of the cases. At a mean of 12 years after the RTSA, the complication rate was 39% of 23, the revision rate was 17%, and the failure rate was 9%. However, the subjective and objective functional outcomes were substantially improved compared with the preoperative status, with a mean gain of 40% in the rCS and of 51% in the SSV at the time of long-term follow-up.

The observed improvement is consistent with previous studies of elderly patients[6,10,11,37] and of younger populations[22-25]. However, in contrast to previous reports on older populations[7,12,38], the outcomes did not decline significantly in our long-term study of younger patients.

In terms of shoulder function, active external rotation remained unchanged from the preoperative to the postoperative evaluations except in patients with a concurrent latissimus dorsi transfer, which improved active external rotation. While Sirveaux et al.[16] reported that the CS and active external rotation are correlated with the state of the teres minor muscle, the present results, albeit in a small series of patients, did not confirm that finding. Also, neither advanced arthropathy nor previous failed surgery significantly affected the functional outcome. Previous studies demonstrated variable influence of these factors on outcome[8,10,16,24,25], and we are unable to explain these differences in the literature. However, they are likely related to differences in patient selection and observational selection biases.

The functional results of the patients with postoperative complications were inferior to those of the patients without complications. Patients with postoperative complications, however, had significantly inferior shoulder function prior to the RTSA and had similar magnitudes of improvement compared with the patients without complications.

A quarter of the patients rated their postoperative result as only fair. We believe that the less favorable subjective assessment in our study, compared with that provided by elderly patients, is related to higher patient demand and expectations and also to the selection of patients with complex pathological conditions and previous operations. The correlation of the number of previous surgical procedures with higher pain levels and inferior SSVs supports this interpretation.

No glenoid or humeral component loosening was observed radiographically, despite advanced glenoid notching in 29% (6) of the shoulders. Considering that almost 50% (10) of the shoulders had grade-1 notching, the rate of notching is comparable with that in previous studies using humeral implants with an inclination of 155°[6,8,11,24]. The prevalence and degree of inferior scapular notching increased over time, and greater notching was correlated with inferior shoulder function. The effect of inferior scapular notching on shoulder function is somewhat controversial[10,12,16,21,39]; there have been suggestions that notching is associated with poorer outcomes, but a cause-and-effect relationship has not been proven. In our series, patients who ultimately had higher-grade notching had 20° less preoperative active anterior elevation and 19° less preoperative active abduction.

Limitations of this study include the retrospective design with its associated bias, the limited sample size and inadequate power to perform meaningful statistical analyses of subgroups (e.g., based on the specific type of implant used), and the number of different types of previous surgical procedures. Although the indication for all of the RTSAs was a massive, irreparable rotator cuff tear with pseudoparalysis of active anterior elevation, there was some heterogeneity due to different stages of glenohumeral osteoarthritis and numbers of previous surgical procedures.

The findings of this study suggest that, in the absence of treatment alternatives, RTSA is a justifiable treatment for patients with a massive, irreparable rotator cuff tear before the age of 60, despite a high complication rate, and provides substantial and lasting improvement of shoulder function and pain scores. ■

Lukas Ernstbrunner, MD[1]
Aline Suter, MD[1]
Sabrina Catanzaro, RN[1]
Stefan Rahm, MD[1]
Christian Gerber, MD[1]

[1]Department of Orthopedics, Balgrist University Hospital, University of Zurich, Zurich, Switzerland

E-mail address for C. Gerber: christian.gerber@balgrist.ch

ORCID iD for C. Gerber: 0000-0002-4624-8285

References

1. Post M. Constrained arthroplasty: its use and misuse. Semin Arthroplasty. 1990 Oct;1(2):151-9.

2. Grammont PM, Trouilloud P, Laffay JP, Deries X. Etude et realisation d'une nouvelle prothese d'epaule. Rhumatologie. 1987;10:407-18. French.

3. Flury MP, Frey P, Goldhahn J, Schwyzer HK, Simmen BR. Reverse shoulder arthroplasty as a salvage procedure for failed conventional shoulder replacement due to cuff failure—midterm results. Int Orthop. 2011 Jan;35(1):53-60. Epub 2010 Mar 14.

4. Leung B, Horodyski M, Struk AM, Wright TW. Functional outcome of hemiarthroplasty compared with reverse total shoulder arthroplasty in the treatment of rotator cuff tear arthropathy. J Shoulder Elbow Surg. 2012 Mar;21(3):319-23. Epub 2011 Aug 26.

5. Patel DN, Young B, Onyekwelu I, Zuckerman JD, Kwon YW. Reverse total shoulder arthroplasty for failed shoulder arthroplasty. J Shoulder Elbow Surg. 2012 Nov;21 (11):1478-83. Epub 2012 Feb 22.

6. Wall B, Nové-Josserand L, O'Connor DP, Edwards TB, Walch G. Reverse total shoulder arthroplasty: a review of results according to etiology. J Bone Joint Surg Am. 2007 Jul;89(7):1476-85.

7. Guery J, Favard L, Sirveaux F, Oudet D, Mole D, Walch G. Reverse total shoulder arthroplasty. Survivorship analysis of eighty replacements followed for five to ten years. J Bone Joint Surg Am. 2006 Aug;88(8):1742-7.

8. Werner CM, Steinmann PA, Gilbart M, Gerber C. Treatment of painful pseudoparesis due to irreparable rotator cuff dysfunction with the Delta III reverse-ball-and-socket total shoulder prosthesis. J Bone Joint Surg Am. 2005 Jul;87 (7):1476-86.

9. Frankle M, Siegal S, Pupello D, Saleem A, Mighell M, Vasey M. The reverse shoulder prosthesis for glenohumeral arthritis associated with severe rotator cuff deficiency. A minimum two-year follow-up study of sixty patients. J Bone Joint Surg Am. 2005 Aug;87(8):1697-705.

10. Boileau P, Gonzalez JF, Chuinard C, Bicknell R, Walch G. Reverse total shoulder arthroplasty after failed rotator cuff surgery. J Shoulder Elbow Surg. 2009 Jul-Aug;18 (4):600-6. Epub 2009 May 29.

11. Boileau P, Watkinson D, Hatzidakis AM, Hovorka I. Neer Award 2005: The Grammont reverse shoulder prosthesis: results in cuff tear arthritis, fracture sequelae, and revision arthroplasty. J Shoulder Elbow Surg. 2006 Sep-Oct;15 (5):527-40.

12. Favard L, Levigne C, Nerot C, Gerber C, De Wilde L, Mole D. Reverse prostheses in arthropathies with cuff tear: are survivorship and function maintained over time? Clin Orthop Relat Res. 2011 Sep;469(9):2469-75.

13. Jones RB, Wright TW, Zuckerman JD. Reverse total shoulder arthroplasty with structural bone grafting of large glenoid defects. J Shoulder Elbow Surg. 2016 Sep;25(9):1425-32. Epub 2016 Mar 31.

14. Klein SM, Dunning P, Mulieri P, Pupello D, Downes K, Frankle MA. Effects of acquired glenoid bone defects on surgical technique and clinical outcomes in reverse shoulder arthroplasty. J Bone Joint Surg Am. 2010 May;92(5):1144-54.

15. Neyton L, Boileau P, Nové-Josserand L, Edwards TB, Walch G. Glenoid bone grafting with a reverse design prosthesis. J Shoulder Elbow Surg. 2007 May-Jun;16 (3)(Suppl):S71-8. Epub 2006 Sep 20.

16. Sirveaux F, Favard L, Oudet D, Huquet D, Walch G, Molé D. Grammont inverted total shoulder arthroplasty in the treatment of glenohumeral osteoarthritis with massive rupture of the cuff. Results of a multicentre study of 80 shoulders. J Bone Joint Surg Br. 2004 Apr;86(3):388-95.

17. Wagner E, Houdek MT, Griffith T, Elhassan BT, Sanchez-Sotelo J, Sperling JW, Cofield RH. Glenoid bone-grafting in revision to a reverse total shoulder arthroplasty. J Bone Joint Surg Am. 2015 Oct 21;97(20):1653-60.

18. Shannon SF, Wagner ER, Houdek MT, Cross WW 3rd, Sánchez-Sotelo J. Reverse shoulder arthroplasty for proximal humeral fractures: outcomes comparing primary reverse arthroplasty for fracture versus reverse arthroplasty after failed osteosynthesis. J Shoulder Elbow Surg. 2016 Oct;25(10):1655-60. Epub 2016 Apr 18.

19. Jost B, Spross C, Grehn H, Gerber C. Locking plate fixation of fractures of the proximal humerus: analysis of complications, revision strategies and outcome. J Shoulder Elbow Surg. 2013 Apr;22(4):542-9. Epub 2012 Sep 6.

20. Grubhofer F, Wieser K, Meyer DC, Catanzaro S, Schürholz K, Gerber C. Reverse total shoulder arthroplasty for failed open reduction and internal fixation of fractures of the proximal humerus. J Shoulder Elbow Surg. 2017 Jan;26(1):92-100. Epub 2016 Aug 9.

21. Melis B, DeFranco M, Lädermann A, Molé D, Favard L, Nérot C, Maynou C, Walch G. An evaluation of the radiological changes around the Grammont reverse geometry shoulder arthroplasty after eight to 12 years. J Bone Joint Surg Br. 2011 Sep;93 (9):1240-6.

22. Sershon RA, Van Thiel GS, Lin EC, McGill KC, Cole BJ, Verma NN, Romeo AA, Nicholson GP. Clinical outcomes of reverse total shoulder arthroplasty in patients aged younger than 60 years. J Shoulder Elbow Surg. 2014 Mar;23(3):395-400. Epub 2013 Oct 12.

23. Samuelsen BT, Wagner ER, Houdek MT, Elhassan BT, Sánchez-Sotelo J, Cofield R, Sperling JW. Primary reverse shoulder arthroplasty in patients aged 65 years or younger. J Shoulder Elbow Surg. 2017 Jan;26(1):e13-7. Epub 2016 Aug 10.

24. Muh SJ, Streit JJ, Wanner JP, Lenarz CJ, Shishani Y, Rowland DY, Riley C, Nowinski RJ, Edwards TB, Gobezie R. Early follow-up of reverse total shoulder arthroplasty in patients sixty years of age or younger. J Bone Joint Surg Am. 2013 Oct 16;95(20):1877-83.

25. Ek ET, Neukom L, Catanzaro S, Gerber C. Reverse total shoulder arthroplasty for massive irreparable rotator cuff tears in patients younger than 65 years old: results after five to fifteen years. J Shoulder Elbow Surg. 2013 Sep;22(9):1199-208. Epub 2013 Feb 4.

26. Goutallier D, Postel JM, Bernageau J, Lavau L, Voisin MC. Fatty muscle degeneration in cuff ruptures. Pre- and postoperative evaluation by CT scan. Clin Orthop Relat Res. 1994 Jul;304:78-83.

27. Fuchs B, Weishaupt D, Zanetti M, Hodler J, Gerber C. Fatty degeneration of the muscles of the rotator cuff: assessment by computed tomography versus magnetic resonance imaging. J Shoulder Elbow Surg. 1999 Nov-Dec;8(6):599-605.

28. Hamada K, Fukuda H, Mikasa M, Kobayashi Y. Roentgenographic findings in massive rotator cuff tears. A long-term observation. Clin Orthop Relat Res. 1990 May;254:92-6.

29. Melis B, DeFranco MJ, Lädermann A, Barthelemy R, Walch G. The teres minor muscle in rotator cuff tendon tears. Skeletal Radiol. 2011 Oct;40(10):1335-44. Epub 2011 May 24.

30. Walch G, Edwards TB, Boulahia A, Nové-Josserand L, Neyton L, Szabo I. Arthroscopic tenotomy of the long head of the biceps in the treatment of rotator cuff tears: clinical and radiographic results of 307 cases. J Shoulder Elbow Surg. 2005 May-Jun;14(3):238-46.

31. Constant CR, Murley AH. A clinical method of functional assessment of the shoulder. Clin Orthop Relat Res. 1987 Jan;214:160-4.

32. Gerber C. Latissimus dorsi transfer for the treatment of irreparable tears of the rotator cuff. Clin Orthop Relat Res. 1992 Feb;275:152-60.

33. Gilbart MK, Gerber C. Comparison of the subjective shoulder value and the Constant score. J Shoulder Elbow Surg. 2007 Nov-Dec;16(6):717-21.

34. Gerber C, Fuchs B, Hodler J. The results of repair of massive tears of the rotator cuff. J Bone Joint Surg Am. 2000 Apr;82(4):505-15.

35. Sperling JW, Cofield RH, Rowland CM. Neer hemiarthroplasty and Neer total shoulder arthroplasty in patients fifty years old or less. Long-term results. J Bone Joint Surg Am. 1998 Apr;80(4):464-73.

36. Gerber C, Pennington SD, Lingenfelter EJ, Sukthankar A. Reverse Delta-III total shoulder replacement combined with latissimus dorsi transfer. A preliminary report. J Bone Joint Surg Am. 2007 May;89(5):940-7.

37. Zumstein MA, Pinedo M, Old J, Boileau P. Problems, complications, reoperations, and revisions in reverse total shoulder arthroplasty: a systematic review. J Shoulder Elbow Surg. 2011 Jan;20(1):146-57.

38. Cazeneuve JF, Cristofari DJ. Long term functional outcome following reverse shoulder arthroplasty in the elderly. Orthop Traumatol Surg Res. 2011 Oct;97 (6):583-9. Epub 2011 Sep 13.

39. Simovitch RW, Zumstein MA, Lohri E, Helmy N, Gerber C. Predictors of scapular notching in patients managed with the Delta III reverse total shoulder replacement. J Bone Joint Surg Am. 2007 Mar;89(3):588-600.